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Numerical simulation of electrical properties of digital borehole based on multi-scale digital rock physics

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Digital Rock Physics (DRP) has made many useful results in the petrophysics (Saenger et al., 2011). Because of the contradiction between resolution and rock size, DRP can't effectively study the law and mechanism of the impact of macroscopic factors on petrophysical properties of complex reservoir such as sonic, resistivity characteristics. Meanwhile, reservoir rocks are usually highly heterogeneous (e.g., carbonates) and the pore sizes may range over many decades in length scales
(Jiang et al., 2013, Khalili et al., 2013).
Digital borehole model is constructed based on the multi-scale digital rock models. For the target research reservoir, the drilled whole cores are scanned using X-ray CT at a low resolution. Then plug samples and sub-samples from different layers are drilled for higher resolution imaging (CT, SEM, FIB-SEM) and rock physics analysis. Multi-scale digital rock models are constructed by image processing from high to low resolution. The main purpose of digital rock models is to establish the correlations between different properties (porosity, permeability, resistivity, wave velocity, etc.). To construct digital borehole model, electrical borehole images and whole cores are used. The whole cores are changed to porosity volumes according to the multi-scale digital rock models and electrical borehole images are transformed to porosity images by calibration with the shallow resistivity and log porosity (Newberry et al., 1996). By using the multiple point statistics method, we established the digital borehole models layer by layer. In each voxel of digital borehole model, petrophysical properties is assigned according the results from digital rock models.
In order to simulate the electrical properties of digital borehole models, saturation distribution is needed. The LBM method used in digital rock physics is not applicable for digital borehole. Here, we used the displacement method used in reservoir simulation. The finite element method (FEM) is used to simulate the resistivity of digital borehole. The trend of simulated resistivity is coincide with the resistivity logging curve. This means the digital rock model is feasible to reflect the reservoir in vertical direction. Several fractures that have different distance to the borehole wall and different directions are applied in the digital borehole. The influence of fractures is reflected in the resistivity results. As the resistivity simulated by the FEM is the average of 2D plane of digital borehole, the results is not strictly equal to the logging curves. A more reasonable approach that combining the digital borehole model and logging instrument simulation should be considered.

References

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